



Data Article

Dataset of flow experiment: Effects of density, viscosity and surface tension on flow regimes and pressure drop of two-phase flow in horizontal pipes



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ARTICLE INFO

Article history:

Received 6 June 2021

Revised 5 September 2021

Accepted 16 September 2021

Available online 24 September 2021

Keywords:

Horizontal pipe

Multiphase flow

Flow regime

Boundary transition

Density

Viscosity

Surface tension

Pressure drop

ABSTRACT

The dataset associate with the report is the flow experiment data acquired to evaluate the effect of density, viscosity, and surface tension on flow regime and pressure drop of two-phase flow in a horizontal pipe. To collect the data, experiments were conducted using a horizontal flow loop of 9.15 m (30 ft.) pipe length and 0.0254 m (1 inch) pipe diameter with a two-phase air/liquid system. The effect of surface tension was introduced by varying surface tension using the surfactant solution, the viscosity was varied using glycerin, and density was varied by the addition of calcium bromide. The superficial velocity of the liquid ranges from 0 to 3.048 m/sec (0–10 ft/s) and superficial gas velocity ranges from 0 to 18.288 m/sec (0–60 ft/s) respectively.

The flow experiments were conducted at a constant liquid flow rate (fixing liquid rate) and varying the gas rate from minimum to the maximum value in a step-wise manner and then reducing the gas rate from maximum to minimum to see the presence of hysteresis effect. At each step of the experiment, the steady-state condition was observed based on the flow rate and pressure response and data were gather to have sufficient data points. Also, the video of the flow pattern was recorded using a high-speed camera for flow regime identification. Numerous sets of experiments were conducted

DOI of original article: [10.1016/j.petrol.2021.108719](https://doi.org/10.1016/j.petrol.2021.108719)

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to capture the ranges of superficial liquid and superficial gas velocity, density (1–1.5 gm/cc), viscosity (1–3.1 cP), and surface tension (32–70 mN/m).

The data was used to develop the flow-regime map for the different cases and the effect of density, viscosity, and surface tension on flow regime and pressure drop were evaluated based on the boundary transition between different flow regimes. The pressure contour maps were generated to correlate with the flow regime map and their boundary transition. Also, a comparison of the generated data with the models in the literature is presented.

Knowledge of flow regime type is essential for accurate prediction of the pressure drop in multiphase flow. However, to generate these maps a large quantity of experimental data is required and it is not feasible to evaluate the effect of each parameter on the flow regime map and boundary transition. This data-set is important in addressing the effect of fluid properties on two-phase horizontal flow also it will be a potential data-set for comparison as well as the development of multiphase flow modeling.

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Specifications Table

Subject	Engineering
Specific subject area	Multiphase flow in horizontal pipe
Type of data	Excel File Table
How data were acquired	The data were acquired by running the flow experiment on a horizontal flow loop at a specific liquid rate, gas rate, and fluid properties. The liquid rate is fixed using the variable speed drive (VSD) and the bypass valve and gas rate was controlled using a pressure regulator and needle valves placed before and after the pressure regulator. After recognition of the steady-state (based on the flow rate and pressure response) the liquid rate, the gas rate was recorded using a flow meter. Two flow meters were used to measure the liquid flow rate, for low liquid flow rate 1.5–15 l/min and second flow meter 15–100 l/min using Omega-FLR6750D with an accuracy of 2% FS. The gas flow rate measured with gas flow meter of low range 0.35–7 SCF/min (Siargo- MF5700, Accuracy ±0.5 FS) and high gas flow rate 7–20 SCF/min using FLR9710D-BSPP, Accuracy 2% FS. The pressure data were collected using a pressure transducer (Omega DPG 110, Accuracy 0.08%) placed along the pipe, and video is captured using a high-speed video camera through a transparent section of the pipe.
Data format	Raw Analyzed
Parameters for data collection	The data was collected by flow experiment on a horizontal flow loop of 9.15 m (30 ft.) pipe length and 0.0254 m (1 inch) pipe diameter and two-phase air/liquid system. The range of superficial velocity of the liquid is 0–3.048 m/sec (0–10 ft/s) and superficial gas velocity is 0–18.288 m/sec (0–60 ft/s) respectively. The liquid density ranges from 1–1.5 gm/cc, the viscosity ranges from 1–3.1 cP, and surface tension ranges from 32–70 mN/m respectively.

(continued on next page)

Description of data collection	The data were collected by running the flow experiment by fixing the liquid rate for specific fluid properties. The liquid rate is fixed and the gas rate varies from low to high and then high to low in a stepwise fashion. For the individual set of experiments, the fluid properties (density, viscosity, and surface tension) were measured. Other data were collected while running a flow experiment at steady-state conditions. The liquid rate and gas rate were recorded by the flow meters and pressure data is recorded using the pressure transducers and data acquisition system. The video is captured using a high-speed video camera through a transparent section of pipe. The recorded flow rates and pressure drop is used to determine the superficial gas and liquid velocity based on the pipe diameter (0.0254 m ~1-inch) and pressure drop per unit length using the pressure readings from the transducer and distance (7 ft.) between the pressure transducers. The flow regimes are identified by visualization of the flow pattern.
Data source location	Institution: King Fahd University of Petroleum and Minerals City/Town/Region: Dhahran/Eastern Province Country: Saudi Arabia
Data accessibility	With the article
Related research article	Ala S. AL-Dogail, Rahul N. Gajbhiye, Effects of density, viscosity and surface tension on flow regimes and pressure drop of two-phase flow in horizontal pipes, <i>Journal of Petroleum Science and Engineering</i> , Volume 205, 2021, 108719, ISSN 0920-4105, https://doi.org/10.1016/j.petrol.2021.108719

Value of the Data

- The data covers a wide range of density, viscosity, and surface tension which is important for multiphase flow regime and flow regime transition.
- The scientific community and engineers working in different sectors of industries such as petroleum, chemical, and refineries will benefit from data.
- The data provide insight into the fundamentals aspect of the multiphase flow in which fluid properties vary significantly and might be used for developing a model or extends with additional experiments on a wide range of fluid properties.
- The data can be used to address the generalization of the existing flow regimes maps and extend their application where fluid properties differ widely from water and air.

1. Data Description

The data file includes the two excel datasheets. The first datasheet (Flow regime data) includes the data collected for the individual system (Air-liquid) with specific liquid properties (density, viscosity, and surface tension). The system number and the description of the system are indicated in the excel file. Eleven systems with variations in the fluid properties and their description is provided in the excel file. The superficial liquid velocity and gas velocity mentioned are calculated based on the flow rate and the pipe cross-sectional area. The main flow pattern categorization, as well as sub-categories, are mentioned in the excel file.

A brief description of the data presented in excel sheet 1 is given in [Table 1](#). There are eleven systems, each system represents distinct fluid properties. The flow pattern for the set of flow conditions (gas and liquid rate) were recorded through the transparent section at steady state condition and corresponding main flow regime and sub-category of flow regimes are identified and indicated in the excel sheet (Flow regime data).

The second datasheet (Pressure drop data) provides the differential pressure drop (psi) across the 7 ft section of pipe. The pressure drop data is provided for the five systems 1. Air-water (8.33 ppg, 1cP, 70 mN/m) Surface 2. Air-0.5% surfactant (8.33 ppg, 1cP, 32.4 mN/m) 3. Air-30% Glycerine (9.04 ppg, 3.1 cP, 55.4 mN/m) 4. Air-25% CaBr₂-0.004% Surfactant (10.01 ppg, 1.44 cP, 61.6 mN/m) and 5. Air-75% CaBr₂-0.02% Surfactant (12.57 ppg, 2.95 cP, 56.3 mN/m) respectively.

Table 1
Description of eleven systems with distinct fluid properties represented in the dataset.

System No.	System	Liquid density (ppg)	Liquid viscosity (Cp)	Surface tension (mN/m)	Liquid superficial velocity (ft/sec)	Gas superficial velocity (ft/sec)	Main flow patterns	Sub-classification
1	Air-Water	8.33	1	70.5	0.161	1.079	Stratified	Smooth Stratified
2	Air-0.02%Surfactant	8.33	1	59.7	0.161	1.079	Stratified	Smooth-Stratified
3	Air-0.05%Surfactant	8.33	1	54.8	0.161	1.079	Stratified	Smooth Stratified
4	Air-0.1%Surfactant	8.33	1	46.5	0.161	1.079	Stratified	Smooth Stratified
5	Air-0.5%Surfactant	8.33	1	32.4	0.161	1.079	Stratified	Smooth Stratified
6	Air-5%Glycerin	9.05	1.26	66.5	0.161	1.079	Stratified	Smooth Stratified
7	Air-10%Glycerin	8.55	1.41	63.97	0.161	1.079	Stratified	Smooth Stratified
8	Air-20%Glycerin	8.76	1.87	57.3	0.1619	1.079	Stratified	Smooth Stratified
9	Air-30%Glycerin	9.04	3.10	55.425	0.161	1.079	Stratified	Smooth Stratified
10	Air-25%CaBr2-0.004%Surfactant	10.01	1.44	61.6	0.161	1.079	Stratified	Smooth-Stratified
11	Air-75%CaBr2-0.02%Surfactant	12.57	2.952	56.3	0.161	1.079	Stratified	Smooth Stratified

Table 2

Description of five systems with distinct fluid properties and pressure drop across 7 ft pipe section.

System No.	System	Liquid density (ppg)	Liquid viscosity (Cp)	Surface tension (mN/m)	Liquid superficial velocity (ft/sec)	Gas superficial velocity (ft/sec)	Pressure drop (Psi)
1	Air-Water	8.33	1	70.5	0.485	9.717	0.035
2	Air-0.05%Surfactant	8.33	1	32.4	0.485	9.717	0.405
3	Air-30%Glycerin	9.04	3.10	55.42	0.485	9.717	0.18
4	Air-25%CaBr ₂ -0.004%Surfactant	10.01	1.44	61.6	0.485	9.717	0.135
5	Air-75%CaBr ₂ -0.02%Surfactant	12.57	2.95	56.3	0.485	9.717	0.315

Each system represents a specific set of fluid properties. The superficial liquid velocity and gas velocity mentioned are calculated based on the flow rate and the pipe cross-sectional area. The flow pattern is available for air-water and air-surfactant systems.

A brief description of the data presented in excel sheet 2 is given in Table 2. There are five systems, each system represents a distinct set of fluid properties. The pressure drop is measured using transducers placed across the 7ft section of the pipe at steady state condition which is indicated in the excel sheet (Pressure drop data).

2. Experimental Design, Materials and Methods

The experiments were conducted on the horizontal flow loop consisting of a liquid tank, liquid pump, air compressor along with the instruments for control and measurement of the flow rate of individual phases, pressure, and a transparent section for the visualization.

To evaluate surface tension effect Alpha Olefin Sulfonate (AOS) surfactant were added in 0.02%, 0.05%, 0.1% and 0.5% gives surface tension variation of 59.7, 54.8, 46.5, and 32.4 mN/m respectively. The effect of viscosity is evaluated by adding glycerin of 5%, 10%, 20%, and 30% which gives the viscosity variation of 1.26, 1.41, 1.87, and 3.1 cP, respectively. Similarly, the effect of density is evaluated by adding CaBr₂ brine of 25% and 75% giving a density of 1.2 and 1.5 gm/cc. However, the addition of the CaBr₂ brine also affected the surface tension which is compensated by adding 0.004% and 0.02% of surfactant solution with the CaBr₂ brine for better comparison.

The experiment was performed starting with the preparation of the desired liquid solution and pumped through the flow loop using a centrifugal pump along with the air injection in the system by an air compressor. The strategy used in the experiment is by fixing the liquid injection rate and varying the gas flow rate from low to high in a stepwise manner and then from high to low with the same step size in the reverse direction to ensure if there is any alteration in readings. In each stage, the flow rate and pressure profile were observed and sufficient time was provided to reach the system at a steady state. At a steady state, the flow rate of liquid, gas, and pressure data was recorded along with video through the transparent section using a high-speed camera for flow regime visualization. The superficial velocities of liquid and gas were calculated using the cross-section of the pipe and corresponding liquid and gas flow rates. The differential pressure along the section of the pipe was calculated using the pressure readings of the transducers placed across the 7 ft section of the pipe.

Ethics Statement

The author duly adhered to ELSEVIER 'Ethics in publishing' policy. No ethical issues are associated with this work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

CRediT Author Statement

Ala S. AL-Dogail: Visualization, Data curation, Investigation, Formal analysis; **Rahul N. Gajbhiye:** Conceptualization, Supervision, Writing – review & editing.

Acknowledgments

The authors would like to acknowledge the Deanship of Scientific Research (DSR) at King Fahd University of Petroleum & Minerals Saudi Arabia for funding this research work through the research grant (Project # SB171012).

Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:[10.1016/j.dib.2021.107396](https://doi.org/10.1016/j.dib.2021.107396).